EXTENDED ARRAY EVALUATION PROGRAM

Terence W. Harley

Texas Instruments, Incorporated

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13. ABSTRACT

This fifth quarterly report summarizes progress under the Extended Evaluation of ALPA, NORSAR, and VLPE program, Contract number F33657-72-C-0725. Work to date in the following areas is summarized:

- NORSAR long period evaluation
- NORSAR short period evaluation
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SECTION I
INTRODUCTION AND SUMMARY

This fifth quarterly report summarizes progress made during the last quarter, 1 April 1973 to 30 June 1973, on the Extended Evaluation of the ALPA, NORSAR, and VLPE Program being conducted by Texas Instruments Incorporated at the Seismic Data Analysis Center in Alexandria, Virginia. The program consists of the following five tasks:

- Continued evaluation of the long-period Norwegian Seismic Array (NORSAR)
- Continued evaluation of the short-period NORSAR
- Continued evaluation of the stations of the Very Long Period Experiment (VLPE) network
- Evaluation of two advanced processing techniques; the Lamont three-component adaptive filter and the similarity detection algorithm (F-detector)
- Investigations of network processing and analysis techniques, and the seismic network system study.

The software required to perform the evaluation was developed under the previous contract F33657-69-C-1063.

Evaluation of the Alaskan Long Period Array (ALPA) was completed on 31 March 1973. This quarter, a report discussing the final evaluation results was prepared and submitted for approval as Special Report No. 8.

A study of reference waveform matched filtering of Sinkiang events using ALPA data was prepared and is being typed.

Processing of events using NORSAR long-period data continued using August and November 1972 events. Approximately 84 events have been processed from this period. Additional comparisons of multichannel filters (MCF) and beamsteer processors were made using noise data from the full array and partial arrays. MCF processing of 17 August events was completed. A report discussing the results of the evaluation of the long period NORSAR conducted during the year ending 31 March 1973 was prepared and is being typed. This report will be submitted as Special Report No. 7.

Special Report No. 9, discussing the short-period NORSAR evaluation results from last year, was prepared and is being typed. Processing of additional short-period NORSAR data was begun for 200 events from June and July 1972 plus 15 additional presumed explosions.

During this quarter, the evaluation results of the VLPE stations during the past year were presented in Special Report No. 6 which was submitted for approval. Processing of data from the new VLPE stations in La Paz and Matsushiro was begun. The application of matched filters to events from a region in central Asia was begun using data from all available VLPE stations.

This quarter, research into the behavior of the Lamont three-component processor was begun using both single channel and beam data from ALPA and NORSAR. Initial results indicate that substantial improvements in the signal-to-noise ratio of weak signals are available. Software necessary to evaluate the similarity detection algorithm has been written and currently is in final checkout.

Progress in the seismic system study this quarter included definition of system functions for two network configurations. These include data flow, quality control, system control, data storage, and user services.

SECTION II
NORSAR LONG-PERIOD EVALUATION

A. CURRENT STATUS

Routine processing of additional 1972 events was resumed this quarter with 146 events from August and 70 events from November being selected for analysis. Processing of August events is almost complete; a total of 84 events were successfully analyzed. A relatively large number of events from early August were not usable, primarily because of library tape problems. Forty-five events from November have been processed through beamforming, but none has been analyzed as yet.

Twenty-one long noise samples approximately 6 hours in length, have been edited from the period of August through December 1972. Ten samples have been used to compare noise rejection of multichannel and beamsteer filter processors with both full and partial arrays.

The effect of MCF's on event signals was measured on 17 August events. We also intend to examine the usefulness of designing MCF's from noise samples occuring several weeks before or after the event to which they are applied.

Special Report No. 7, describing the results of the evaluation of the NORSAR long-period array during the year ending 31 March 1973, has been completed and is in typing.

B. FUTURE PLANS

Event processing will continue until the completion of the November events. Additional events may be processed if time permits. Noise

analysis and MCF/BS processor comparisons will also continue. Fifteen additional long noise samples will be edited and analyzed.

Two reports will be generated. The first will summarize our evaluation of NORSAR, including data processed during the 1 April to 31 September 1973 period. The second report will discuss combined NORSAR short-period and long-period discrimination results.

SECTION III
NORSAR SHORT-PERIOD EVALUATION

A. CURRENT STATUS

Routine processing of the short-period events which comprise the data base for Special Report No. 9 was completed during this quarter. The total data base accumulated so far comprises 344 events, including 21 presumed explosions, 15 of which are from Eurasia.

Processing was initiated for another 220 Eurasian events from the June and July 1972 event lists plus 15 1971 and 1972 presumed explosions from Eurasia that have not previously been processed. At the present time processing of these events is about half complete.

Preparation of Special Report No. 9 was completed during May, and this report is now being typed. A maximum-likelihood method was applied to estimate the 90 percent incremental detection threshold of the NORSAR short-period array, based on data from this report. Estimates were $m_b = 4.2$ for all of Eurasia and $m_b = 4.5$ for the Japan-Kuriles-Kamchatka region. Short-period discrimination results were encouraging for Eurasian events, but did not appear to be promising for events from the Western Hemisphere. As expected, however, SP discriminants were still inferior to $M_s - m_b$ and other combined SP-LP criteria in separating Eurasian earthquakes and presumed explosions.

B. FUTURE PLANS

Efforts during the next quarter will be focused upon completing the necessary processing for the Final Report of the NORSAR Short-Period

Evaluation Program. The accumulated data base for this report should be close to 600 Eurasian events, including almost 40 presumed explosions. It is hoped that this event ensemble will make feasible a detailed evaluation of the various short-period discriminants and their potential in complementing combined SP-LP discriminants.

SECTION IV
VLPE EVALUATION

A. CURRENT STATUS

During this quarter, Special Report No. 6 entitled, "Evaluation of the Detection and Discrimination Capabilities of the Very Long Period Experiment (VLPE) Single Stations, VLPE Network, and the VLPE-ALPA-NORSAR Combined Network", was completed and submitted for approval. We continued the processing and analysis of Eurasian events of August and November 1972 for the VLPE sites reported in Special Report No. 6 and two new sites, La Paz, Bolivia (ZLP) and Matsushiro, Japan (MAT).

The application of chirp and reference waveform matched filters is in progress for all available VLPE sites and for Eurasian events having epicenters located within 38° to 46°N latitude and 70° to 90°E longitude.

A letter report entitled, "Structure of Long-Period Low-Level Vertical Earth Noise", was submitted to Dr. C. F. Romney (ARPA/NMRO). In addition, a study of the relationship of peak trace amplitude to that of the RMS was initiated during this period.

B. FUTURE PLANS

Determination of the detection and discrimination capabilities will continue for the approved list of Eurasian events of December 1972 and January 1973 for the VLPE sites reported on in Special Report No. 6, and the two new sites, ZLP and MAT.

Chirp and reference waveform matched filtering will continue for the December-January Eurasian events having epicenters located within 38° to 46°N latitude and 70° to 90°E longitude.

The study of the relationship of peak trace amplitudes to RMS will be completed before the next reporting period. Further, the study of the long-term noise levels and spectral estimates for ZLP and MAT will be initiated shortly.

SECTION V
RESEARCH

A. CURRENT STATUS

During the past quarter, the Lamont processor was run on four single station events, two from the summer and two from the winter. Using a wide range of signal-to-noise ratios, each event was buried in an hour-long noise sample preceeding the event. Signal-to-RMS noise ratios of the raw signals, of the Lamont-processed signals, and of the bandpassed (0.024-0.059 Hz) signals, were computed. Peak/RMS amplitude statistics of the pure noise were also measured. Gains of the Lamont processor over unprocessed signals, and over bandpassed signals were computed for each signal and signal-to-noise ratio. In the absense of propagating noise, at signal-to-noise ratios where the event was undetectable on the raw traces, the Lamont processor improved the signal-to-noise ratio up to 8 dB. Effects due to propagating and non-propagating noise were considered.

The Lamont processor was also applied to beamsteer outputs for twenty events. Analysis of the results has not yet been completed.

The software for implementing the detector was written and debugged during this period.

B. FUTURE PLANS

The range over which improvements in signal-to-noise ratio due to Lamont processing can be computed will be extended downward. Analysis of Lamont processed beams will be undertaken, to determine improvements in S/N and in detection level. Beams will be formed from individual

Lamont processed sites, and the performance of this procedure compared to that of Lamont processing beams. Chirp filters will be applied to Lamont processed beams to determine their utility. The processor will be run on synthetic noise data to determine the rate, if different from zero, at which the processor generates apparent signals from pure noise.

The Fisher detector will be run on several long noise samples at various azimuths, and compared to the beam power detector. The detector's statistics and false alarm rate as a function of integration length and output level will be determined. Rejection of off-azimuth events and the effects of irregularities in the data will be determined and compared to theoretical values calculated earlier.

SECTION VI
SEISMIC NETWORK SYSTEMS STUDY

A. CURRENT STATUS

The seismic monitoring system has been described functionally by specifying in detail the operations to be performed by the system. The specific plans for realizing the desired operations will be described in subsequent parts of the study. Data flow and control, quality checking and control, and data bank and other user's data services are functions to be provided for by the system. A categorical description of the baseline hardware configuration is also included with the functional definition. The functional description of the system is provided separately for a network of predominantly single instruments along with several arrays, designated as network A; and an improved standardized network of long-period (LP) and short-period (SP) arrays, designated as network B.

The two seismic networks are comprised of: 17 WWSSN stations and five arrays for the SP network A, and 17 WWSSN stations, five VLPE stations and five arrays for the LP network A; 25 standardized SP and LP arrays for network B (each of the 25 sites has both a SP and a LP array) to coincide with the network A station locations whenever practical. Maps were generated showing both the SP and LP capabilities of networks A and B. Similarly, maps were generated showing the location capability for SP magnitude 4.0 events for both networks.

B. FUTURE PLANS

Detailed descriptions of the capability of several detector algorithms for the station processor are being prepared. These include beamed

sums, F-statistic, and max-like signal estimation. The relative advantages of these estimates in detecting given signals and eliminating various categories of false alarms will be considered.

Algorithms for automatically associating individual station detection data currently are being studied. Such algorithms are important not only from an operating efficiency standpoint, but also in determining individual station detection strategies.

Communications and data collection techniques are being defined for networks A and B. Algorithms for efficient coding of the station detection bulletins to allow low rate data communications are under consideration.

The functional definition of the system will be expanded to include review and update procedures necessary to monitor and improve system performance.